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C5E EDA ETF

(56) Documents cited
GB 2186283 A US 4589434 A US 3590919 A

(58) Field of search
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INT CL^5 C10G, F17D
WPI: CLAIMS

(54) **Subsea piping method and plant**

(57) In a method for preventing formation of hydrates in subsea pipelining of hydrocarbon flows the phase diagram for a said flow including a hydrate line is established and the hydrocarbon flow is separated under a pressure at which light hydrocarbons boil from the liquid phase and enter the gas phase to such an extent that hydrates will not be substantially formed in the liquid phase. The gas phase is processed so that formation of hydrates is prevented during the subsequent piping. A suitable subsea plant includes a separator (2) for separation of the well flow into liquid and gas, connection means (10) for connection of the separator to a well flow pipeline (1), a pump unit (3), a compressor unit (4), fluid conveying pipelines between the separator and the pump unit and the compressor unit respectively and pressure lines from the pump unit and the compressor unit respectively connected to the conveying pipelines (6, 8) and a choke device (31) in the pipeline 1 for reduction of the pressure in the separator (2) and a control device for the adjustment of the choke device (31) in accordance with the pressure desired in the separator (2).

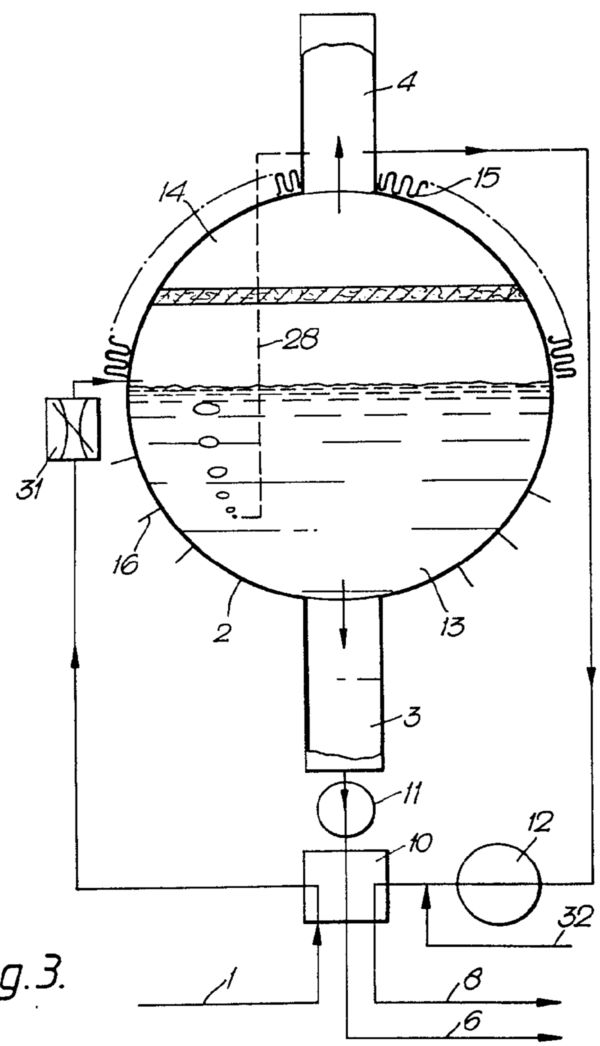

Fig.3.

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Fig.1.

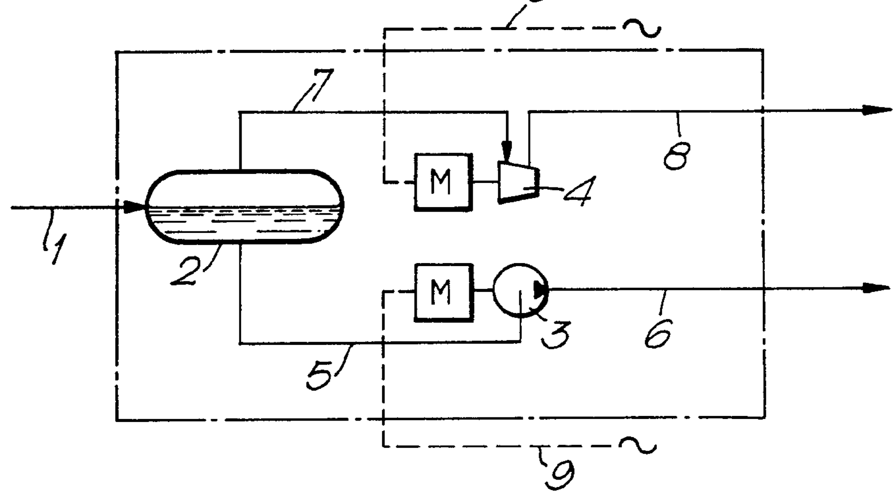
9
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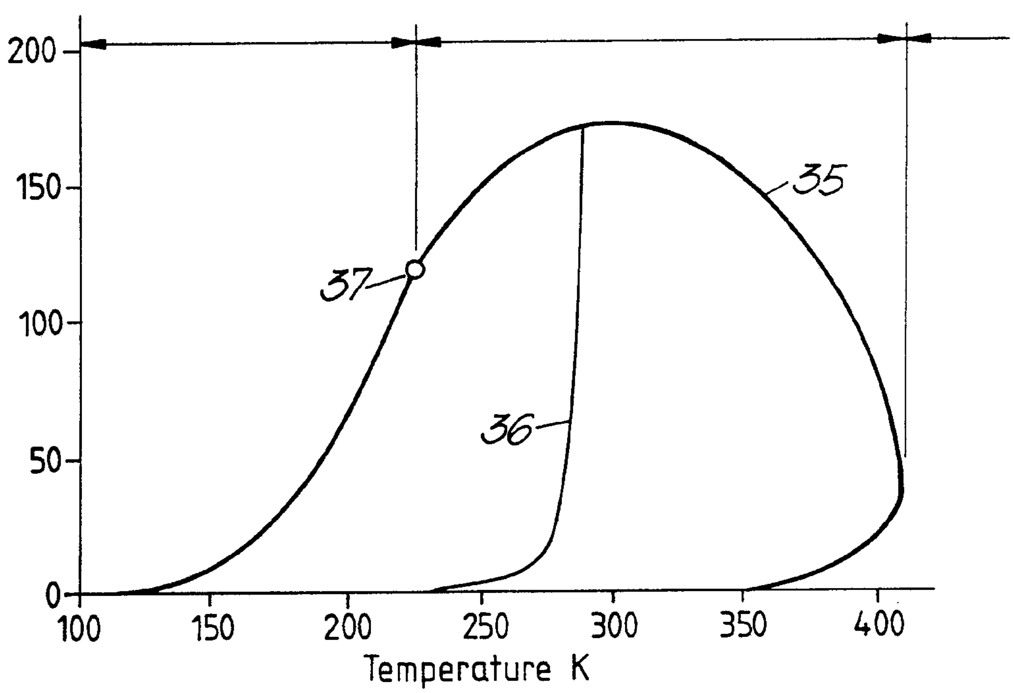
Fig.2.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Temperature K

Fig.3.

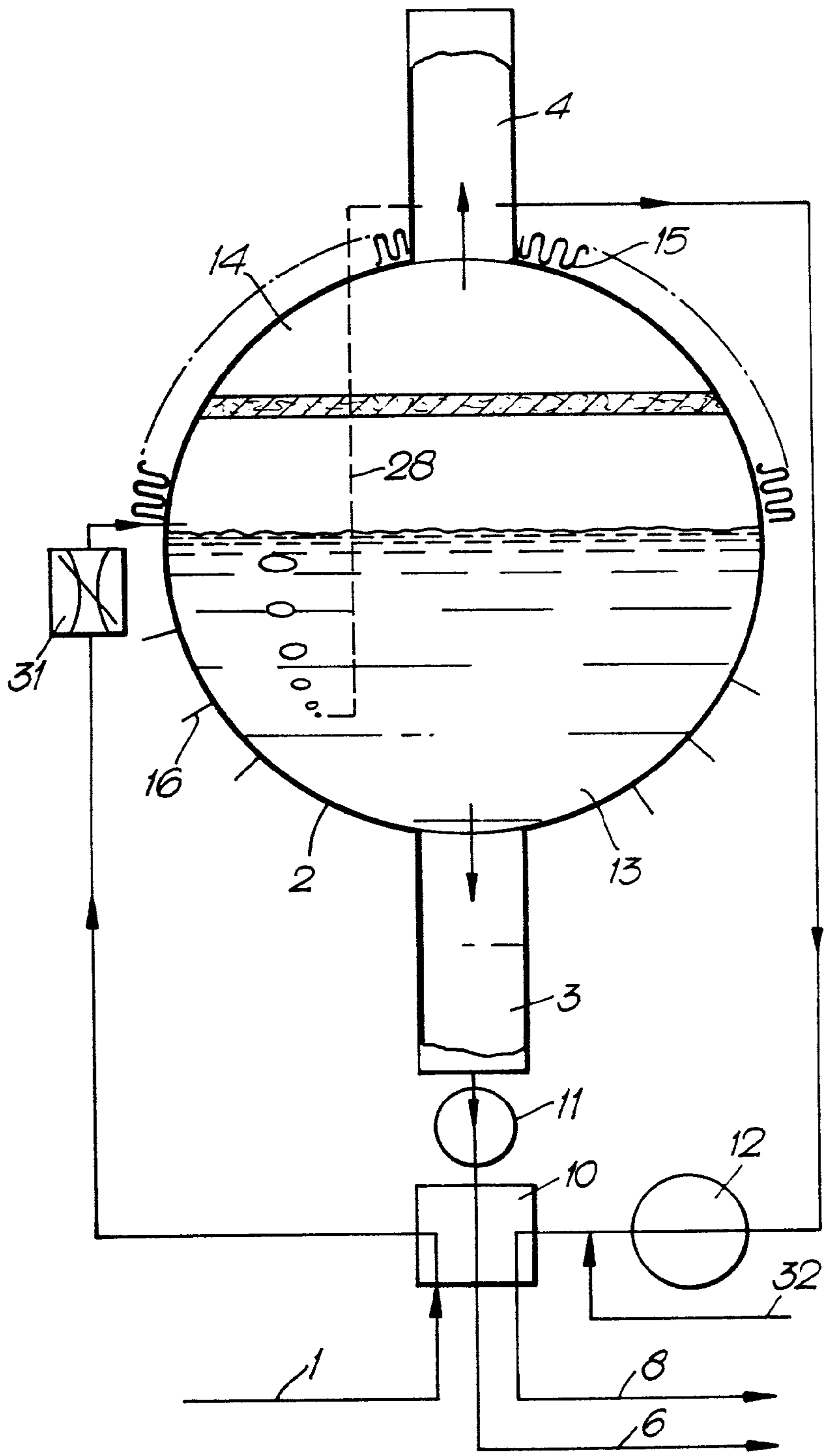


Fig.4a.

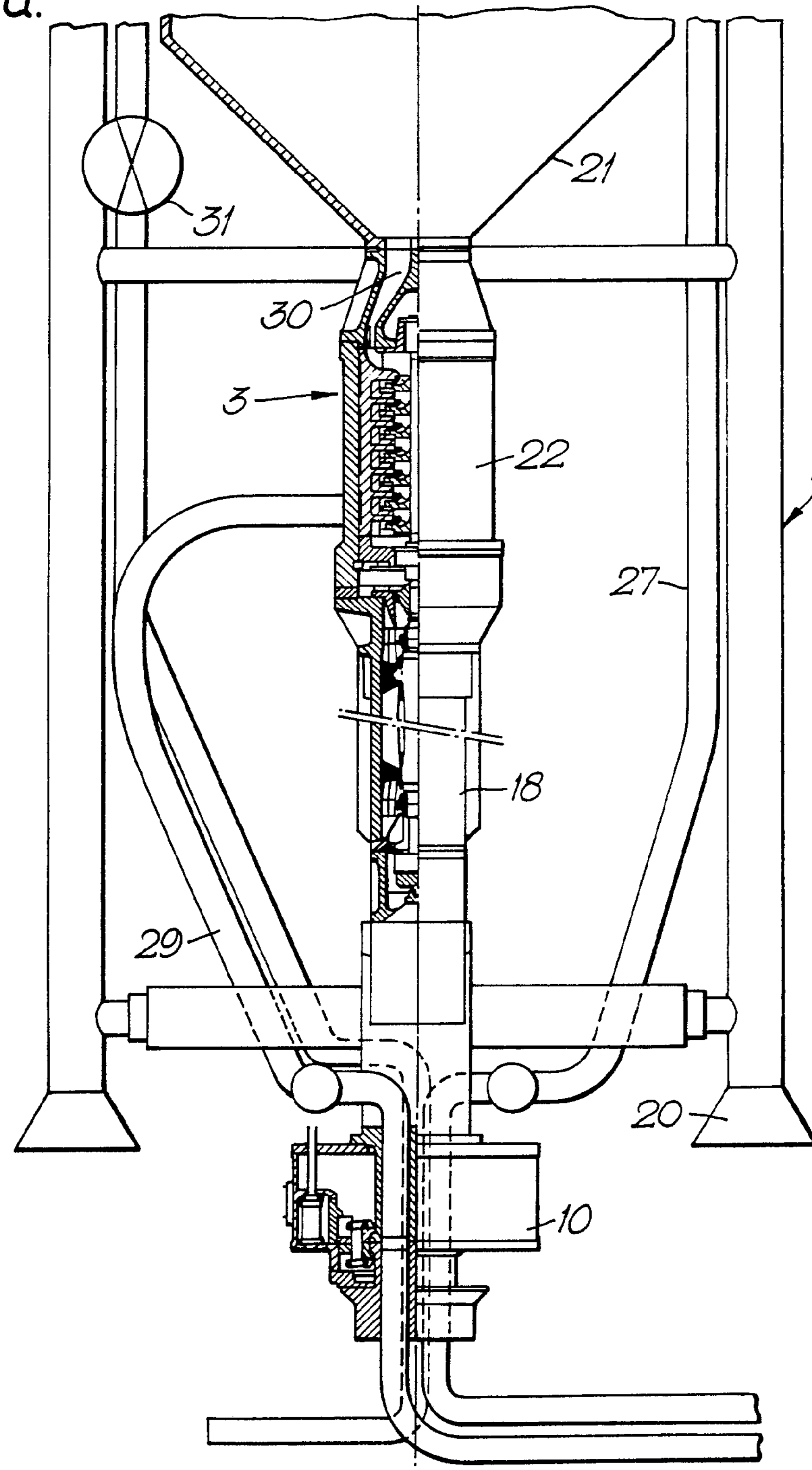


Fig. 4b.

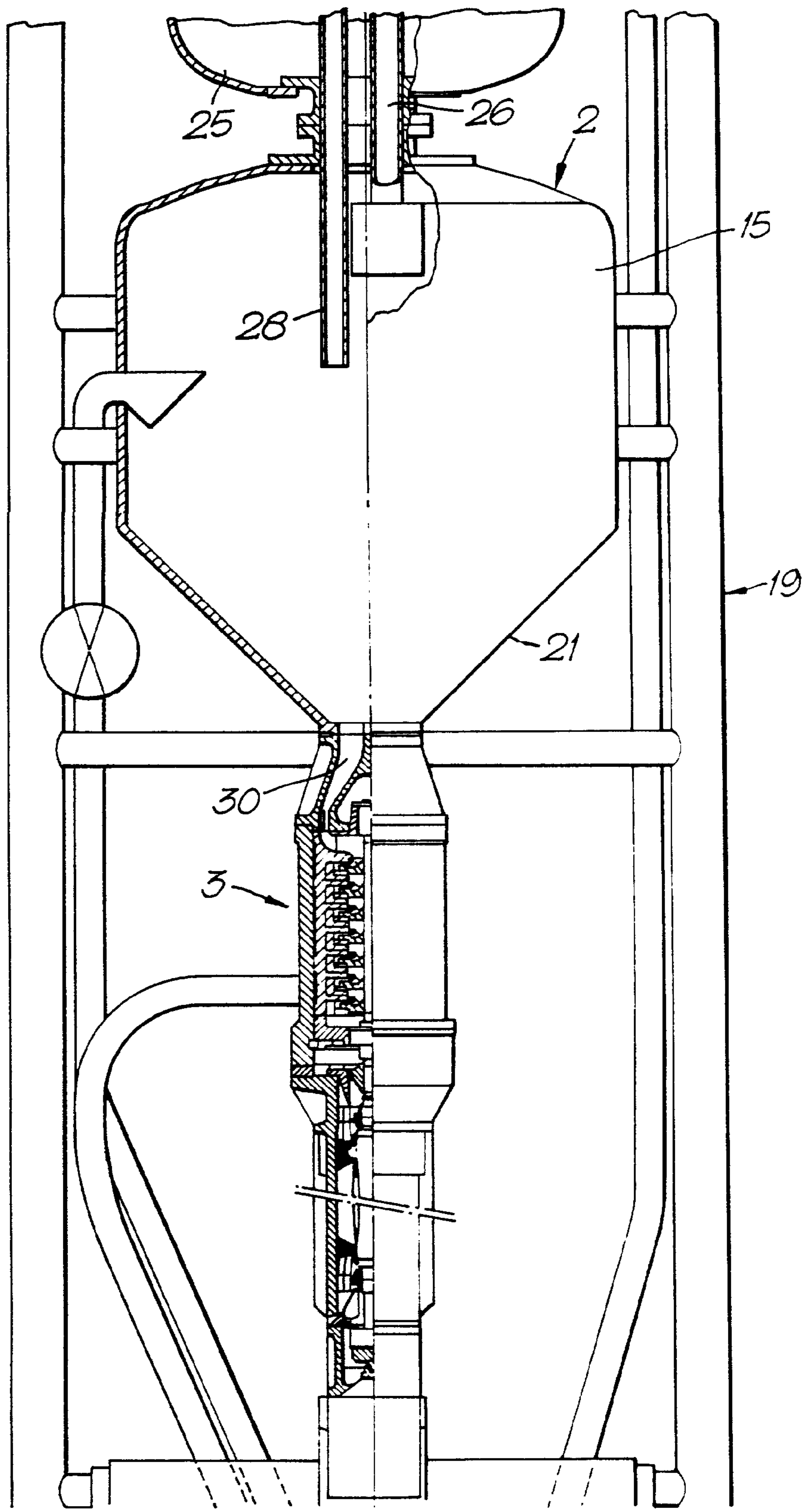
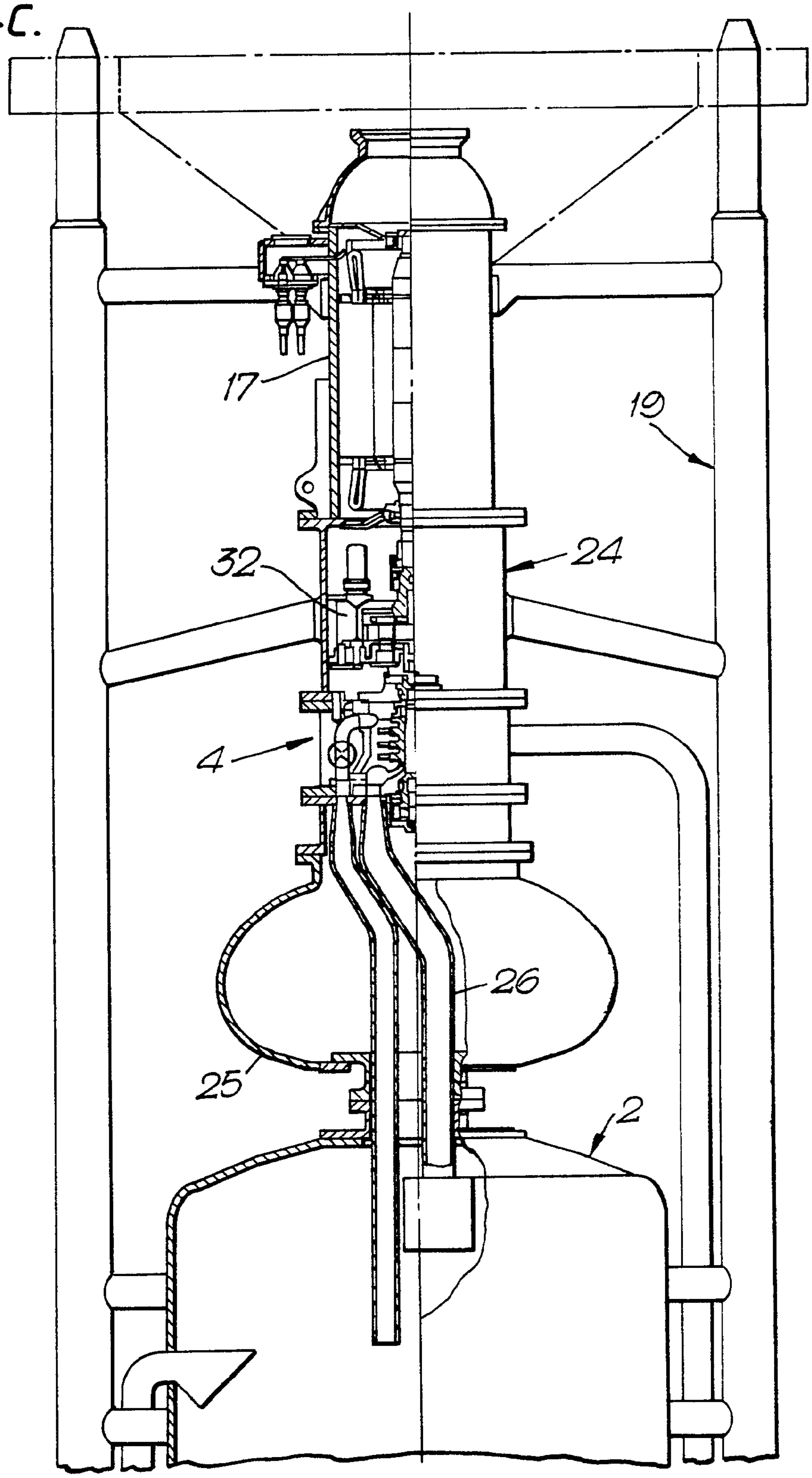


Fig.4c.



SUBSEA PIPING METHOD AND PLANT

This invention relates to a method of preventing formation of hydrates in hydrocarbon flows in subsea pipelines.

The invention also relates to a subsea plant for processing of a well flow to prevent hydrate formation during subsequent piping in pipelines, including a separator for separation of the well flow into liquid and gas, connecting means for connection of the separator to the well flow line, a pump unit having a pump with a motor and a compressor unit comprising a compressor with a motor together with fluid conveying pipelines between the separator and the pump and the compressor respectively and a pressure pipeline from the pump and the compressor respectively connected to the actual pipelines.

When conveying flows of hydrocarbons in subsea pipelines, the formation of hydrates in the pipelines presents a problem. The conditions for formation of hydrates (which is a form of ice) in pipelines where hydrocarbons are conveyed, are present when the flow of hydrocarbons contains light hydrocarbon components, particularly paraffins, and free water and the temperature is below a certain level, for example 18^{o}C, (and the pressure simultaneously is above a certain level).

The conditions for formation of hydrates which are thermodynamically defined, can be found quite accurately for a given mixture of hydrocarbons containing water by constructing a so-called phase diagram for the mixture and by inserting a so-called hydrate line in same. A skilled person will be acquainted with approved computer programs able to insert the hydrate lines when the composition of the hydrocarbon mixture is known. The effect of hydrates in a pipeline can vary from harmless,

i.e. the hydrates are entrained in the well flow to the processing plant in which they are dissolved (melt) without actually being discovered, to the more serious situation where hydrates will block a pipeline completely as an "ice plug" and consequently stop production. In the latter case the pipeline must be pressure released so that the hydrates will melt. This may take several days.

Normally formation of hydrates is counteracted by injections of either methanol or glycol into the pipeline. This method is, however, for economical reasons limited to pipelines for gas/condensate. As a rule about half a liter of injection fluid must be added per liter free water. This addition will be acceptable in gas/condensate pipelines, but not in multiphase pipelines which may convey several thousand cubic metres of water per day.

A further possibility of limiting hydrate is by insulating the pipeline but this will only have effect as long as there is a fluid flow through the pipeline. Prior to a possible shut down, methanol (or glycol) must be injected, or the pipeline may have heating cables which are connected during a shut down, or the pressure in the pipeline must be released. These methods are expensive and no well-developed technology is available for this purpose.

The object of the present invention is to prevent formation of hydrates in a simple and cost effective way.

According to the invention there is provided a method of preventing formation of hydrates in hydrocarbon flows in subsea pipelines wherein the phase diagram for the hydrocarbon flow with a hydrate line is established and the hydrocarbon flow is separated at a pressure at which the light hydrocarbons boil from the liquid phase and enter the gas phase to such an extent no hydrates or substantially no hydrates will be formed

in the liquid phase, as determined by the composition of the hydrocarbon flow and the gas phase is processed in such a manner that the formation of hydrates is prevented during subsequent piping.

The invention is based on the use of phase diagrams established for the compositions of the well flow in question and on the concept that it is primarily the light hydrocarbons which form hydrates. The light hydrocarbons are removed from the well flow by separating the well flow into liquid and gas. The water is entrained in the liquid. The gas phase contains water vapor up to saturation. It has been found that in practice satisfactory conditions will be obtained at only 40 bar. It is important that the pressure is reduced to a level at which the conditions in the phase diagram are fulfilled to such an extent that the formation of hydrates is prevented in the liquid phase.

It is advantageous for the processing of the gas phase to include injection of compounds counteracting the formation of hydrates, as for example methanol and ethylene glycol.

During the subsequent piping of the well flow it is possible, by simple means, to obtain the desired pipeline pressure in the gas and liquid provided by the separation.

Said separation pressure may be provided by a choking of the pressure in the hydrocarbon flow.

A particularly advantageous method of preventing formation of hydrates during subsea piping of hydrocarbon flows is a method utilizing a subsea station for pumping of a well flow, the well flow being conveyed in the subsea station through a separator and further through a pump and a compressor respectively, the method being characterised by the feature that, in order to prevent formation of hydrates, the separator is operated with a controlled pressure which results in the boiling

off of a satisfactory portion of light hydrocarbons from the liquid phase to enter the gaseous phase so that no hydrates or substantially no hydrates are formed in the liquid phase in which most of the water is present, the conditions being defined by the composition of the well flow and by processing of the gas phase so that hydrate formation is prevented.

The formation of hydrates can, for example, be prevented by injection of compounds such as methanol and glycol counteracting hydrates in the gas phase. Heating is also a possibility.

As mentioned, the invention also provides a subsea plant for processing of a well flow to prevent formation of hydrates during subsequent piping, including a separator for separating of well flow into liquid and gas, connecting means for connecting the separator to a pipeline carrying the well flow, a pump unit including a pump with a motor, and a compressor unit comprising a compressor with a motor, together with fluid conveying pipelines between the separator and the pump and the compressor respectively and a pressure pipeline from the pump and the compressor respectively connected to pipelines for the well flow, the plant being characterised by choke means in the well flow pipeline to reduce the pressure in the separator and control means for controlling the choke means in accordance with the desired pressure in the separator. This pressure will be the pressure which, according to the phase diagram with the hydrate curve is sufficiently low to enable boiling of the desired quantity of light hydrocarbons from the liquid phase and into the gas phase.

It is advantageous to have injection means for injection of compounds counteracting formation of hydrates in the pressure line for the compressor.

The invention will now be explained in more detail with reference to the drawings on which:

Figure 1	shows diagrammatically a subsea station with separator, pump and compressor,
Figure 2	shows a typical phase diagram for a well flow,
Figure 3	shows diagrammatically the lay-out of the station, and
Figures 4a, b and c	show half sections through a practical embodiment of a subsea station in accord with the invention.

The subsea plant shown diagrammatically in Figure 1 is a subsea station for production of hydrocarbons. The station includes a separator 2, a pump 3 and a compressor 4. A well flow comprising oil, water, gas and particles is supplied to the separator 2 through a pipeline 1 from one or more well heads (not shown) on the sea bottom. From the fluid chamber in the separator a pipeline 5 extends to the pump 3. This pipeline will consequently convey a mixture of oil, water and particles. In the pump 3 the liquid flow is propelled through the pipeline 6. From the gas chamber of the separator a pipeline 7 leads to the compressor 4. At this point the gas is propelled through the pipeline 8.

The motors for the pump 3 and the compressor 4 are referred to as M. The supply of electricity to the motors is referred to by the broken lines 9.

In Figure 3 is shown in principle how the subsea station can be constructed as a compact unit. The same reference numbers as in Figure 1 are used for the corresponding components in the station.

As is evident from Figure 3, the separator 2, the pump 3 and the compressor 4 (the motors are not shown in Figure 3) are assembled as a compact unit with the three components arranged in the column structure shown, with the pump at the bottom, then the separator and with the

compressor at the top. The fluid carrying pipelines 1, 6 and 8 are assembled in a common connecting unit 10 at the bottom of the column structure. In the gas pipeline 8 a volume flow meter 12 may be included. In the same way a meter 11 may be included in the line 6. The pipeline 1 is provided with a choke 31 close to the separator.

Injection means are indicated at 32.

The pump 3 has its inlet directly connected to the liquid chamber 13 in the separator, and likewise the inlet of the compressor 4 is directly connected to the gas chamber 14 of the separator.

Both units, i.e. the pump unit with the pump 3 and also the compressor unit with the compressor 4 are self draining, i.e. gas is able to bubble up from the pump and liquid can drip down from the compressor.

It is advantageous if the gas chamber 14 of the separator is insulated with the insulation 15 as shown. The liquid chamber 13 of the separator can with advantage be provided with cooling ribs 16. These features aid stabilization of the phases, i.e. the liquid phase and the gas phase.

Figure 4 discloses a preferred embodiment of a subsea station in the form of a compact unit including a separator, a pump and a compressor which is adapted to be located on the sea bottom. The unit shown on Figure 4 has an advantageous size corresponding to a blow out preventer (BOP). This unit can be installed using a drilling rig or a modified diving vessel.

The same reference numbers are used on Figure 4 as in Figures 1 and 3 for the corresponding components in these Figures. The separator 2 is in Figure 4 in the form of a container having a cylindrical upper section and a conical bottom section and the pump is here in the form of a multistage centrifugal pump while the compressor 4 is constructed as a multistage rotational

compressor. These components are as shown assembled into a compact unit in a column structure. At the bottom there is provided a common connection unit or connector 10.

The compressor as well as the pump are in Figure 4 designed as vertically positioned centrifugal machines. The motor 17 for the compressor is at the top and the motor 18 for the pump is located under the pump in the column structure. The motors are vertically positioned electric motors (asyncronous motors) with separate RPM-control.

As shown in Figure 4, the column structure is built into a frame work 19 which includes guide funnels 20 for cooperation with guide posts in a standard module pattern in a manner known *per se*, for example as known from blow out preventers and other kinds of equipment, which are adapted to be lowered and installed on the seabed in a desired position.

The gas chamber of the separator may be heat insulated as indicated by the reference number 15. The liquid chamber of the separator may have cooling means, for example external cooling ribs not shown on Figure 4, but as disclosed in Figure 3 where the cooling ribs are referred to as 16.

The pump 3 and its motor 18 are located in a common, closed pressure housing 22. The pressure housing is assembled from a plurality of closely assembled housing sections.

The compressor 4 and its motor 17 and gearing 32 are also arranged in a common pressure housing 24 constructed from a plurality of closely assembled housing sections by means of the flange connections shown.

The pressure housing 24 is at its lower end designed as a supply 25 for lubricating oil for lubrication of the bearings in the compressor unit.

The suction side of the compressor 4 is directly connected to the gas chamber of the separator 2 by means of a pipe 26. The pressure side of the compressor is connected to the pipeline 27, extending downwardly on the outside of the column structure to the connector 10. A pipe connection 28 extends from the pressure side of the compressor for return of gas of the separator. The pipeline 28 extends down into the liquid chamber of the separator.

The pressure side of the pump 3 is by means of a pipeline 29 in connection with the connector 10. The connector 10 has three passages. A passage through the connector 10 establishes connection between a well flow pipeline 1 (see Figure 3) and a pipeline conveying the well flow to the separator via an adjustable choke 31 as shown diagrammatically in Figure 3 and Figure 4. The plant shown in Figures 1, 3 and 4 may with advantage be used for working of the method according to the invention, but before the method or the operation of the plant is further explained a short description of the so-called phase diagram for the well flow is now given.

A typical phase diagram for a light hydrocarbon deposit is shown in Figure 2. The pressure is given in bars along the ordinate. The temperature, given in ^{o}K, is indicated along the abscissa.

The curve 35 represents the so-called two phase envelope. The steeply rising curve 36 represents the so-called hydrate line. The critical point of the liquid is on curve 35 at a point indicated by 37. To the left of the critical point 37 the diagram includes a region referred to as "oil". To the right of the point 37 the diagram includes a region referred to as "condensate". This region covers as shown a remaining part of the two phase envelope 35. To the right there is an additional region which in the diagram in Figure 2 is referred to as "gas".

These references show that there will be liquid outside the envelope 35 and to the left of the critical point in the diagram. Inside the envelope 35 in the region "condensate", condensate will be precipitated and further to the right there will be gas only at the temperature/pressure combinations outside the envelope 35.

The hydrate line 36 is established in a manner known *per se*. As mentioned previously there are available approved computer programs for this work when the composition of the hydrocarbon mixture is introduced. In the diagram, to the left of the hydrate line, there will be comparatively low temperatures and hydrates may be formed. To the right of the hydrate line in the diagram there will be no formation of hydrates. An ordinary well flow will usually be within the envelope for the two phase condition. In order to avoid formation of hydrates it is for example possible to inject methanol or ethylene glycol. This has the effect that the hydrate line will move to the left in the diagram and consequently provide a separation between the pressure/temperature profile of the pipeline and the hydrate line obtained by the injection so that formation of hydrates is avoided. Alternatively an insulation of the pipeline will contribute to maintain the well flow to the right of the original hydrate line.

Over longer distances it will usually be not possible to maintain the flow in the pipeline outside the hydrate forming region (to the right of the hydrate line) due to cooling and temperature drop. By initial separation of the well flow into a liquid phase wherein most of the water is present and a gas phase in which the light hydrate-forming hydrocarbons are present, these phases can be represented separately in a phase diagram. At a sufficiently low level of separation pressure the phase diagram for the liquid mixture will

show a hydrate line at a sufficiently low temperature level that the liquid flow will be maintained above the temperature at which hydrates can be formed. The phase diagram for the gas will have a hydrate line at a higher temperature level and the temperature of the gas flow in the pipeline will sooner or later drop and intersect the natural hydrate line. The hydrate line for the gas phase can, however, be moved to a lower temperature level by means of the above mentioned previously known injection methods as the water content in the gas phase is now small.

With the plant described above, i.e. the subsea station comprising a separator, a pump and a compressor close to the wells, it is possible when piping is initiated, to achieve efficient control of hydrates by separation of light components from the multiphase flow near the hydrocarbon wells. It assumed that the composition of the well flow is known from tests taken or in other ways. With this background it is possible to calculate how low the pressure in the separator 2 must be to boil off a sufficient proportion of the light hydrocarbons so that the hydrocarbons will enter the gas phase. The separation pressure is decided either by providing that at no point during the operation of the liquid pipe will there exist temperature/pressure combinations falling within the hydrate region (during interruptions the pipeline will for example have to be pressure released to avoid formation of hydrates); the gas pipeline 8 is injected with small quantities of methanol or ethylene glycol; or provision is made to maintain the pressure sufficiently low that light hydrocarbons will be transferred from the liquid phase to the gas phase to such an extent that no hydrates can be formed in the liquid pipeline even during complete interruption of the flow for an indefinite time. (It may be a question of lowering the pressure down to a

level below 20 bar).

A condition for use of this method is that the described subsea station is available with separator/ pump/compressor from the first day hydrocarbons are conveyed through the pipeline, and not after, and increase of pressure is required due to a falling pressure in the reservoir in order to maintain a satisfactory pipeline flow.

The method according to the invention is naturally associated with additional costs compared to those methods which can be collectively referred to as "not doing anything". The additional costs are primarily due to the requirement of an investment in the subsea station several years before it is normally required due to unsatisfactory pressure in the reservoir. The subsea station will consume more energy than is required only to increase the pressure from the reservoir pressure prevailing at the station, the additional lowering of the pressure down to a level for correct separation will also have to be continuously compensated. In relation to methods involving multiphase conveyance in one pipeline also investment must be made in an additional gas pipeline after the subsea station. The cost of this pipeline will primarily be related to the length of the pipeline and its diameter. If there is a probability of formation of hydrates, "not doing anything" will not be a relevant means for comparison. Economy and technical conditions relating to the method of reducing pressure by use of a subsea station will therefore have to be compared with other relevant methods in order to decide the competitive relation in each case.

The method proposed in accord with the invention is considered to be of advantage and competitive compared with other possible methods.

CLAIMS:

1. A method of preventing formation of hydrates in hydrocarbon flows in subsea pipelines wherein the phase diagram for the hydrocarbon flow with a hydrate line is established and the hydrocarbon flow is separated at a pressure at which light hydrocarbons boil from the liquid phase and enter the gas phase to such an extent that no hydrates or substantially no hydrates will be formed in the liquid phase as determined by the composition of the hydrocarbon flow and the gas phase is processed in such a manner that the formation of hydrates is prevented during subsequent piping.

2. A method as claimed in claim 1 wherein the processing of the gas phase includes injection of one or more compounds counteracting hydrate formation.

3. A method as claimed in claim 2 wherein the components counteracting hydrate formation include methanol or glycol.

4. A method as claimed in any one of the preceding claims wherein the gas and liquid involved by the separation are pressurized to the desired pressure for subsequent pipelining.

5. A method as claimed in any one of the preceding claims wherein said separation pressure is provided by a controlled choking of the flow pressure in the hydrocarbon flow.

6. A method of subsea pipelining of a hydrocarbon flow, using a subsea station for pumping of a well flow, the well flow being conveyed at the subsea station through a separator and from the separator through a

pump and a compressor respectively wherein the separator, in order to prevent formation of hydrates, is operated at a controlled pressure resulting in a boiling off of a sufficient proportion of light hydrocarbons from the liquid phase to the gas phase, so that no hydrates or substantially no hydrates are formed in the liquid phase in which a major part of the water is present, determined by the composition of the well flow and the gas phase is processed so that formation of hydrates is prevented.

7. A method as claimed in claim 6 wherein said treatment of the gas phase includes injection of one or more compounds counteracting formation of hydrates.

8. A method as claimed in claim 7 wherein said compounds include methanol or glycol.

9. A subsea plant for processing of a well flow to prevent formation of hydrates during subsequent pipelining, including a separator for separating the well flow into liquid and gas, connection means for connection of the separator, a well flow pipeline, a pump unit comprising a pump with a motor and a compressor unit comprising a compressor with a motor, and fluid conveying pipelines between the separator and the pump and the compressor respectively and a pressure line from the pump and the compressor respectively connected to the conveying pipelines, and further comprising a choke device in the well flow pipeline for reducing the pressure in the separator and control means for adjusting the choke device in accordance with the desired pressure in the separator.

10. A subsea plant as claimed in claim 9 further comprising an injection device for injection of

compounds counteracting formation of hydrate in the pressure line to the compressor.

11. A method as claimed in claim 1 or claim 6 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

12. A subsea plant as claimed in claim 9 substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

13. Use of the method as claimed in any one of claims 1 to 8 or claim 11, or the plant as claimed in claim 9, claim 10 or claim 12, in the pipelining of subsea well hydrocarbons.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number: 9108543.1

Relevant Technical fields

(i) UK Cl (Edition K) C5E (ETF, ETG, EDA, EDB)

(ii) Int Cl (Edition 5) C10G; F17D

Search Examiner: K MACDONALD

Databases (see over)

(i) UK Patent Office

(ii) WPI; CLAIMS

Date of Search: 17.9.91

Documents considered relevant following a search in respect of claims 1-13

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
Y	GB A 2186283 (HUMPHREYS & GLASGOW) figures 1 and 2 and description relating thereto	at least Claim 1
Y	US 4589434 (KELLEY) column 3, lines 29-31	"
Y	US 3590919 (TALLEY) figure 2 and description relating thereto	"

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

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